Cost-Benefit Study of: Upgrading County Highway A and County Highway N to All-Season Highways in Bayfield, Wisconsin

Updated April 10th, 2022

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Introduction

Bayfield County, home to the Apostle Islands National Lakeshore, is a destination. The county's sandstone cliffs, quaint towns, and remote wilderness attract tourists from across the nation. Its stunning landscape brings visitors and shapes its economy. The landscape also supports the county's largest economic sectors: tourism and forestry. Bayfield County manages the largest forestry operation of all 72 Wisconsin counties. Timber sales in Bayfield County's forests bring in over $3 million to the county each year.[i] This is matched by national forest proceeds from the Chequamegon Nicolet National Forest. The county contributes significantly to Wisconsin's forest economy, with has an economic impact of $24.7 billion in products, and $4 billion in labor income. Forestry is a significant sector to the state, comprising 2% of its total GDP.[ii]

The southern segment of County Highway A and the western segment of County Highway N run through the heart of Bayfield County forests. These roads provide direct access to almost 30% of county forest land and almost 15% of the Chequamegon-Nicolet National Forest. However, this road's foundation is not stable enough to support heavy loads during the spring thaw, a period of about two months every year, beginning in March and ending sometime in May. The county imposes load restrictions for vehicles over 14 tons during the spring thaw period. This prevents logging trucks from accessing forest lands. Removing the road restrictions lets timber companies harvest more, increases the value of timber tracts, and increases employment in the forestry sector. The proposed project would strengthen the base and sub-base of the road eliminating the need for seasonal load restrictions. It would also widen and provide even slopes to the shoulders and resurface the entire 22-mile stretch of road.

While the largest monetary benefit of improving the road leads to increased forestry activity, other significant benefits exist. Widening and improving slopes of the shoulders improves road safety for motor vehicles and bicycles. Paved shoulders may also increase bicycle traffic and improve the county's marketability as a bicycle destination,[iii] already known as a tourism and outdoor sports destination. Resurfacing the road improves the time required to travel the segment of road for trucks, commuters, and tourists alike. Other benefits of the

project include reduced emissions and alternate natural disaster detour routes, an increasingly important factor for this region. A notable benefit that this analysis is unable to estimate is the increase in value of privately-held forest lands along the project route. Along the southern edge of Highway N in the town of Barnes, nearly all forested lands are privately held. This area, totaling some 25 square miles, will likely see similar stumpage price increases as logging interests will be able to access the land during all seasons. Sales of timber on private property are not subject to the same reporting requirements as publicly-owned forests and data on the stumpage price paid to private sellers is unavailable. Therefore, we cannot estimate the impact of this project on privately-held forest lands, though they are likely to be significant.

To analyze the costs and benefits of the proposed highway reconstruction, we assembled all available data on costs and benefits of the project. The project life (the usable life of the topcoat of pavement on the project area) extends 20 years past the completion of construction, and the improved base of the project has a life longer than 20 years. We conducted a Monte Carlo Sensitivity Analysis to account for key uncertainties in our projections. The Monte Carlo analysis projects positive net benefits for both a no-build scenario and a scenario where the project is completed. Total quantifiable benefits were approximately $8.6 million greater in the build scenario. Our project scenario provides a conservative under-estimate for the benefits of this project and may not capture all benefits that the road improvement provides to Bayfield County.

Building All-Season Economic Development in Bayfield County

Spring Thaw Restrictions

Each spring, Northern Wisconsin, Minnesota, Michigan, and other northern states and provinces impose vehicle restrictions on certain roads. During the spring thaw, a period lasting roughly two months from the beginning of March to the beginning of May, roads in northern regions are subjected to wide variation in temperatures. Cold nights and warm afternoons mean that some roads can see fluctuation in temperatures of up to 100°F.[iv] The state of Wisconsin classifies as having a wet freeze, which is characterized by meltwater, condensation,

and general moisture leaching into the soil during the winter months that alternately freezes and thaws, damaging the road structure.[v]

These wide swings in temperature put stress on the roadway and can degrade road surfaces. To reduce damage to roads, Bayfield County restricts the types of vehicles that can use most county highways.[vi] Single axle vehicles weighing more than 6 tons per axle, and tandem axle vehicles weighing more than ten tons per axle group are banned from using most lettered county highways.[1]

Bayfield county coordinates with neighboring Ashland and Douglas counties when it imposes and releases spring load restrictions. The counties use a frost tube to measure how deeply the soil has thawed. When the readings show that the soil is sufficiently dry and unlikely to refreeze, roads are re-opened for all vehicles in all three counties.[vii] As Northern Wisconsin's springs grow warmer and wetter,[viii] the length of time that spring load restrictions are in force is expected to increase. For this analysis, we assume that spring load restrictions will be in force for a period lasting between 59 and 65 days over the next twenty years. We also assume that the likelihood that spring load restrictions lasting longer than 61 days increases each year during the twenty-year study period, which translates into a 17% closure rate of the roadway. For a greater discussion of these assumptions see Appendix A.

Current Road Conditions

PASER Assessment

In 2021, Bayfield County conducted a study of each of its county highways to assess road quality. The county used the PASER (Pavement Surface Evaluation and Rating) system, a standard means of identifying and comparing the quality of roads. PASER was developed at the University of Wisconsin-Extension and is used by state and local government in Wisconsin to assess the quality of the pavement on the state's roadways.[ix]

[1] Exceptions to this rule include dairy trucks, emergency vehicles like ambulances or fire trucks, septic tank trucks, school buses, and heating fuel trucks.

PASER uses a 1 to 10 scale to describe road conditions. A road scoring a 10 appears as if it has recently been paved, with virtually no wear and tear. A road scoring a 1 has failed, showing extensive loss of surface integrity and is in need of immediate repair involving a total reconstruction. Road quality has been shown to directly impact the speed at which travelers can drive; lower PASER scores imply increased travel times.[x]

The portion of Highway N of interest to this report received good scores in the most recent evaluation. The 5.8-mile section of Highway N running from Wisconsin Highway 27 to the southern terminus of Highway A received a 7 rating. This section of the road is in good condition, requiring only preservative treatment such as crack sealing.

The portions of Highway A of interest to this report received middling scores in the most recent evaluation. The 3.2-mile segment of Highway A running from Iron Lake Road in Iron River to Ruth Lake Road scored a 6. This section of the road is in good condition, with "slight surface raveling," and "well-sealed" cracks. It needs only preservative treatment such as a seal coat.

The 1-mile section of Highway A running from US Highway 2 and the 12.1-mile section of Highway A running from Kelly Lake Road to Ruth Lake Road received a 5 rating. This section of the road is in fair condition, with visible cracking in the pavement and moderate raveling in wheel paths. Roads that receive 5 ratings typically are structurally sound but need a seal coat to preserve the pavement surface.

The southernmost stretch of Highway A, a 1.2-mile section running from Kelly Lake Road to Highway A's terminus at Highway N received a 3 rating. This indicates that the road is in fair condition, showing "significant signs of aging" including wide raveling, and long cracks or deep rutting in wheel paths. Roads in this condition typically need a structural overlay of 2 inches of asphalt or more to bolster their structural integrity. This is among the lowest quality roads currently in Bayfield County and will need significant maintenance regardless of whether or not the rest of the Highway A project occurs.

Appendix B presents mapped PASER assessments of Bayfield county's county highways and an inset of the stretch of Highway A discussed in this report.

Traffic Counts

In 2009, the Wisconsin Department of Transportation (WisDOT) conducted traffic counts along sections of Highway A. The counts were conducted in five locations: one at the north end of the project area, about a half mile south of Highway A's intersection with U.S. Route 2; one near Highway A's southern terminus at Highway N in Barnes; two on Highway N, west of its intersection with Highway A; and one on Highway N, east of its intersection with State Highway 27.[xi] (A map of these locations and counts is provided in Appendix C.)

Since 2009, continuous traffic counts in Northern Wisconsin (including in Sawyer, Douglas, Iron, and Washburn counties) have generally increased.[xii] We assume that traffic on Highway A has similarly increased. This report created estimates of current and future traffic on Highway A based on a formula created by Saha and Fricker (1988).

There are several ways of estimating future traffic volume. Many communities use Travel Demand Models, which take into account the number of trips to particular destinations. However, Travel Demand Models are typically only used by metropolitan communities with regular commuter flows. Bayfield County falls outside a Metropolitan Planning Area and is therefore not covered by a Travel Demand Model.[xiii] Research has shown that in rural areas, traffic volume is largely influenced by an area's population.[xiv] For the five counties (Bayfield, Washburn, Douglas, Iron, and Sawyer) in Northern Wisconsin for which routine traffic count data could be found, there was a generally positive relationship between a county's population size and the traffic volume. The Saha and Fricker (1988) model uses an interaction between state and county population. Empirical tests have shown that their model can regularly predict traffic counts in rural areas within 5% of the observed count. While more accurate and sophisticated models to predict future traffic volume exist, they do not work well in a rural area like Bayfield County, where there is not a clear nexus for commuters. State and County population projections are easily available and can provide reliable estimate of county traffic growth. See Appendix D for estimates of traffic volume growth.

Benefits and Costs

Forestry

Forestry and logging are important industries in Northern Wisconsin and statewide. Timber sales in Bayfield County's forests bring in over $3 million to the county each year.[xv] These sales provide the predominant source of revenue for the county's Forestry and Parks Department and add to the general fund. Each year, Bayfield County foresters identify forest parcels to be harvested, or trees within parcels that should be cut to thin the forest. The county sets a minimum bid price for each parcel and places the parcels up for auction each May and November. Loggers bid for the exclusive right to harvest the designated wood from the county's forests for a period of two years (though extensions may be granted). The revenue from these bids goes to Bayfield County's budget. In 2017, forest sale revenues accounted for 10% of the county's $30 million dollar budget.

Nearly 30% of county forests in Bayfield County are adjacent to the west side of Highway A. Timber sales along Highway A regularly earn the county more than $1 million, representing about a third of all county forest sale revenues. Nearly 15% of the Chequamegon-Nicolet National Forest is adjacent to the east side of Highway A. Each spring, all of these forests are affected by the seasonal load restrictions that close Highway A.

Seasonal load restrictions limit marketability of this land. In a survey of Bayfield area residents, logging respondents reported planning their timber harvest around load restrictions or stacking timber in the forest until it could be removed.[xvi] This limits a forester's ability to sell product when the market is strong. In similar surveys from Minnesota, the same patterns emerge: logging companies will shift their production to other areas during seasonal load restrictions or will curtail harvesting entirely.[xvii] Seasonal load restrictions can incur costs on both logging respondents and sawmills. In Bayfield County, 13% of logging respondents reported stacking their timber until seasonal load restrictions were lifted and the harvest could be moved. When timber is stacked in late winter and early spring, it dries out slightly before being transported to mills. After wood is harvested, loggers are often paid by weight,[2] dry wood earns less than it would if it had been delivered to the mill soon after it was cut.[xviii] Additionally,

2. Most mills scale the timber by weight. When mill tickets are sent to Bayfield County, the county converts the weight scale into cords. The logger pays then Bayfield County by the cord which was calculated based on weight.

brittle wood is more prone to splintering while it is being processed at sawmills, costing sawmills an estimated $50,000 per day.[3]

Seasonal load restrictions may add distance and time to a trucker's route to a sawmill. With relatively small profit margins (one study estimated them at less than 15%[xix]), logging respondents pay less for remote timber parcels, other things equal. One study found that parcels farther from towns as small as 500 people received less than similar parcels near towns: for each additional kilometer from a town, a parcel's value declined by 1.3%.[xx] 80% of logging respondents in Bayfield County said that they would be willing to place higher bids for timber tracts near Highway A if the highway were made into an all-season road.[xxi]

Road Maintenance

All season roads have a deeper base course and subbase course and thicker layers of asphalt, providing more drainage and making them more resilient to seasonal expansions and contractions than standard arterial roads. This allows heavy trucks to use the road during the spring thaw without damaging the road. Thicker pavement brings other advantages, too. Rural interstates designed to all-season standards can withstand forty times more ordinary wear and tear than normal rural arterials.[xxii] In Bayfield County, crack-sealing and pothole filling were typically needed on county highways less than three years after a highway had been recoated, but all-season roads lasted five years before similar maintenance was necessary. Improving Highway A to be an all-season road will reduce annual routine maintenance costs, make the road surface smoother for a longer period of time, and thus improve quality of life for those residents using the road.

Furthermore, improving Highway A to all-season standards will likely reduce winter maintenance costs. In addition to making Highway A's road bed deeper, this project will widen the road's right-of-way, clearing trees from the road's area and allowing more sun to radiate to the roadway. After a right-of-way widening project on state Highway 13 in northern Bayfield

3. Seasonal variation in the availability of timber also requires sawmills to keep large inventories of timber to maintain workloads during restricted periods, incurring further costs.
Demchik, Michael; Joseph Conrad; and Melinda Vokoun. 2016. "The Scale and Cost of Seasonal Timber Harvesting Restrictions in Wisconsin." *Wisconsin Council on Forestry*. Access at: https://councilonforestry.wi.gov/Documents/PracticesStudy/SeasonalHarvestRestriction.pdf.

County, transportation engineers said that less salt was needed to melt snow on the sunnier road. In all, it is estimated that allowing more sun to radiate on the roads will cut winter maintenance costs by as much as 20%.

Travel Times

In order to find the value of reductions in travel time rendered by the highway improvement project, our analysis must consider two factors: the value of each driver's time and the amount of time saved by the improvement in road quality.

Value of Time Assumptions

To approximate each driver's value of time, we split the drivers into three categories: truckers, local commuters, and tourists. Each driver category's value of time was based on a commensurate wage and with the overall value based on the averaged the income for the three main categories of drivers. Using trends identified in a similar rural highway analysis in New Mexico,[xxiii] we assumed 5% of the drivers are local commuters. To approximate the value of time for commuter vehicle drivers, we used Bayfield County's per capita income, $33,151.[xxiv] We converted this to an hourly wage of $15.94/hour. We assumed commuters have an average of one occupant per car.

We then calculated the number of expected logging trucks based on the cords harvested annually from the timber tracts along Highway A and the timber's destination. The timber tracts accessed by this route supply between 80,000 and 100,000 cords of wood annually. A standard logging truck carries between 6 and 12 cords of timber. Assuming full capacity for each truck, we constructed truck traffic flows based on the quantity of timber received from Bayfield County forests at regional sawmills. We assumed trucks travel the route with the least distance using only state highways. We further assumed that trucks have only one occupant per car.

Once we calculated the average number of trucks per day per road segment, we could establish the hourly value of time for truckers. The average hourly wage for truck drivers in the state of Wisconsin is $27.96/hour.[xxv] We distributed this assumption over a uniform distribution with upper and lower bounds of plus and minus 5%. We lack the information to create a normal distribution for the vehicle composition of these roads.

We assume that the remainder of the vehicles are drivers visiting Bayfield County for tourism. We assumed that visitors to the county come from the nearby metropolitan areas of Duluth, Minneapolis-St. Paul, and Madison. To approximate their value of time, we averaged the median income of these three metropolitan areas and calculated an hourly wage of $19.10. We assumed 1.75 adult tourists per vehicle, based on estimates from Bayfield County professionals and a 2015 study on travel time savings from New Mexico.[xxvi]

Road Quality Benefits to Travel Time Assumptions

Having established the total hourly value of time for the proposed stretch of road, the amount of time saved by the improvement in the quality of the road can be established. Based on the PASER Rating data from Bayfield County (see Appendix B), the proposed stretch of road falls under the categories of 7 - 3, which are at the low end of "good" and high end of "poor".[xxvii] Barring a major reconstruction project like the one proposed, the road will likely continue to deteriorate. County officials report that county road quality drops one by one unit about every two years; if the proposed project were planned for 2023, 2024, and 2025, the no-build road would have a quality of between 4 and 1. At present levels, the road still has relatively good structural integrity, but its surface is aging. The aging surface experiences "raveling," or the loss of fine and coarse surface aggregate, longitudinal cracking, and transverse cracking. This type of aging leads to an increase in the surface roughness of the road itself that might cause drivers to decrease speed below the speed limit.

The roughness of the road surface is measured using the International Roughness Index (IRI). The IRI is based on the ratio of a standard vehicle's accumulated suspension motion (that is, how much the wheels need to move up and down while traveling on the road) divided by the distance traveled by the vehicle during the measurement. The higher the IRI, the greater the roughness of the road. Simply put, the IRI is measuring how "bumpy" of a ride one experiences on a given stretch of road. The lower the IRI, the less bumpy the road.

While there is not a direct conversion from PASER to IRI, it is assumed that the categorical descriptions of PASER levels 5 and 4 imply a less-than-perfect IRI. For reference, a well-maintained airport runway will have an IRI of 2, new road pavement will have an IRI of

between 1.5 and 3.5, older pavements will have an IRI up to 6, and unpaved gravel roads can have an IRI of 8 or more.[xxviii] We can assume, in the case of the Bayfield County road improvement program, that there will be some improvement to road quality in terms of IRI. This improvement could lead to faster travel times.

Based on a study performed by Caltrans and the University of California Pavement Research Center, the relationship between road surface quality and driver speed is as follows: "a one unit change of IRI (63 inches/mile) only leads to about a… 0.3 to 0.4 mph change in free-flow speed…" A graph showing this phenomenon can be found in Appendix E, figure 2.9. It should be noted that the researchers indicate that "the conclusion from this study cannot be generalized to very rough roads or to larger IRI changes."

Assuming that the road project will improve the IRI of the road by at least one "unit," we can assume that all drivers will, on average, be able to drive 0.3 to 0.4 mph faster. This is also assuming that drivers might already drive below the speed limit due to road quality, a sentiment expressed in survey responses and personal testimony from Bayfield area truckers. The speed increase equates to a 2 second reduction in travel time per every 5 miles of new road traveled. Multiplying that reduction by the number of miles, the average daily traffic on each stretch, over 365 days and an average time value of $14.43 per hour per driver provides an expected annual benefit. Because this benefit extends 20 years into the future over the expected lifespan on the road, it is necessary to discount its value. Discounting its value allows us to obtain the present value of the benefit. Per DOT recommendations, we discounted this benefit at a 7% rate over 20 years. After discounting, the present value of the travel time improvement is $3,764.67.

Employment

Bayfield county administered a survey to gather data on possible employment benefits as well as other benefits which we may have overlooked while developing our analysis. The survey had 97 respondents. Please see more detailed survey results in Appendix H. In the survey, eleven logging respondents indicated that they would hire as many as 22 new employees if Highway A were upgraded to an all-season road.[xxix]

Estimating the economic impact of added employment is difficult. Bayfield County has an unemployment rate that is higher than the state average, so job growth could bring formerly unemployed people back into the labor market. Since we are estimating the change between the no-build and the project scenario, the former employment status of a new logger matters. We do not have data on whether a newly hired logger was previously unemployed, if he or she was a truck driver, or if he or she was hired at a higher wage from a rival company.

For the purpose of this analysis, we estimate that newly employed loggers would have come out of unemployment as a result of hiring spurred by increased economic activity from the all-season road. Though unemployment depredates a person's wages and well-being, unemployed people are not considered to be destitute in cost-benefit analyses. The opportunity cost of their time—the leisure time that they give up to pursue a full time job—is typically treated as equal to half the wage of their new job.[xxx] We estimate that newly employed loggers would earn the median annual salary for their occupation ($45,000)[xxxi] plus benefits. We estimate the opportunity cost of their time as equal to half that.

Road Safety

The improved Highway A would widen and pave shoulders as well as add rumble strips to the road. Such improvements have been shown to reduce car crashes by giving motorists more room to navigate hazards on the road as well as keeping motorists alert. Studies have found that widening the width of the shoulder from one to nine feet can reduce car crashes by, on average, 16% in rural areas.[xxxii] Rumble strips may reduce car crashes by a similar amount. The State of Wisconsin uses a standard "Crash Modification Factor" (CMF), based on empirical research, to estimate the effect of different countermeasures on roads.[xxxiii] We used these CMFs to estimate a range of reductions in car crashes.

To estimate the cost of crashes, we used historical crash data provided by Bayfield County. This data listed all the crashes along the project area from 2017 to 2021, as well as the number and severity of injuries from each crash. In the past five years, there have been 26 crashes, which resulted in 8 injuries, along the project route (see Appendix I for the number of crashes and injuries per year along the project route). The Federal Highway Administration provides a standard estimate of costs of car crashes, based on the severity of injuries.[xxxiv] In a

crash where no one is injured, for instance, the cost of insurance claims, cleaning the road, and other damages, is estimated at $7,126 (see Appendix J for all costs and an explanation of the rating system).

Scrap Value

The scrap value of a project is its worth at the end of its useful life. In the case of a paved road the pavement, in this case asphalt, can be recycled and used in the rehabilitation of the road. The old asphalt would be stripped from the road surface and reprocessed, either on site or at an off-site facility, and turned into recycled asphalt pavement (RAP). The use of RAP is a burgeoning cost-saving tool for road rehabilitation and construction. Using RAP can save agencies money on the cost of virgin asphalt, transportation of materials, and energy use.[xxxv] According to the Wisconsin Highway Research Program, parties constructing roads in Wisconsin can use up to 20% RAP in their asphalt mixtures for surface layers and up to 45% for lower and foundation layers.[xxxvi]

The scrap value of the proposed road project is essentially the same as its value as recycled asphalt pavement. At the end of the proposed road's life, it could be recycled, mixed with new binders and aggregate to be laid back down for decades of continued service.

Difficult-to-Quantify Benefits

Emissions

There are many benefits of road construction that are difficult to quantify. In addition to improvements in travel time this project will in some way affect vehicle emissions. While improvements in road quality have been shown to reduce vehicle emissions[xxxvii], exact impacts of the proposed project on net amount of traffic generated in the region are uncertain. On top of time and emissions changes, improving Highway A will likely reduce the amount and cost of traffic collisions. Estimating the magnitude of this change is difficult because there have been too few accidents to develop a statistically significant model of traffic accidents along the project route.

Bicycling

Tourism is one of Bayfield County's largest economic drivers. Both tourists and residents enjoy the County's natural beauty, rolling hills, and stunning views of Lake Superior. A popular outdoor recreation activity is cycling. Bayfield County's North Coast Cycling Association hosts five road bike events annually, each of which attracts tourists from around the region.

County Highway A is recommended as a low-traffic route for cyclists by the Ashland and Bayfield County Tourism departments.[xxxviii] Highway A is flat, scenic, and leads to a bicyclist-friendly diner at the intersection of Highway A and Highway N.[xxxix] However, in a survey of Bayfield County residents and businesses, three respondents indicated the quality of the road was too poor to safely bike. They also suggested the frequent truck traffic creates a need for a paved shoulder to protect bicyclists from accidents with heavy vehicles. Under the proposed project, cyclists could take advantage of a safer, smoother route. It is likely more cyclists would use the route, because the other convenient north-south route is a busier state highway.

Encouraging bicycling has other benefits as well, including those to health and public safety. While they are difficult to quantify, increased physical activity has positive health benefits for those who participate. Increased bicycle-ability of roads could reduce the number of personal motor vehicles on the road, making those roads safer and reducing air and noise pollution. Another benefit of making Bayfield's highways more bike-friendly is the positive impact on tourism. As mentioned before, the Bayfield County Tourism Department recommends Highway A as a scenic, low-traffic bicycle route; the proposed project would help the area to live up to that recommendation.

Natural Disaster Detours

In Bayfield County, floods have washed out each state highway in only the past two years, forcing detours for high-traffic routes. Historically, flooding of this magnitude is uncommon, and it is difficult to predict the probability of future floods. However, as Northern Wisconsin becomes wetter, and catastrophic flooding events happen more frequently, the need for duplicate routes that can be used during detours becomes more pressing.

In the event of a natural disaster, County Highway A could provide an efficient north-south detour to all traffic if it met state highway standards. The increased lane and shoulder width of the proposed road as well as the increased foundational depth and road height would

make this important route even more resilient to infrastructure-crippling natural disasters like flooding. The proposed road improvement falls on the westernmost north to south road in Bayfield County and could potentially serve an important role in addressing catastrophic events like flash floods or forest fires. In June, 2018, flash floods washed out large sections of Bayfield County's roads, rendering them unusable. Traffic on U.S. Route 2 was redirected onto a nearly 50-mile detour, to Wisconsin State Highway 13, near the shores of Lake Superior.

Predicting natural disasters is becoming more and more difficult, as is estimating the value of natural disaster mitigation. This analysis cannot estimate the probability that Wisconsin State Highway 27 or U.S. Route 63 are washed out. However, the construction of a more resilient all-season highway would add a detour that the county could use in the instance of a weather emergency. As an all-season road, Highway A would have improved slopes and better drainage, mitigating the risk of floods washing out the highway. An all-season Highway A would also be graded so as to allow traffic to move faster along the highway, accommodating greater traffic in the event of an emergency as well as allowing heavier emergency vehicles to pass through the area faster.

Methodology

Timeframe

This analysis is projected over the course of the "usable life of the project," the point at which the project route would need serious rehabilitation to remain useful. For this project, we use a twenty-year time frame from the completion of the last segment of Highway A in 2025. Our annual projections of costs and benefits run from the present year (period 0), 2022, through twenty-three years to 2045 (period 23).

All values are expressed as their present values in 2022. Future costs and benefits are discounted to reflect the future value of money. People tend to place greater value on present cash flows than expected cash flows at a future date. This report uses a discount rate of 7%, compounded annually, as prescribed by the U.S. Department of Transportation.

Routine Maintenance

In order to project the useful lifetime of the road in its current state, the analysis included an extrapolation of current traffic data into a standardized amount of damage caused by each vehicle. Using the "equivalent single axle load" (ESAL) measurement, the amount of traffic on each segment of the road project was converted into a standardized dataset. According to the Federal Highway Administration, rural arterials in wet freeze climates can sustain roughly 980,000 ESALS before they reach "terminal serviceability", or a quality level below that which the state has determined to necessitate reconstruction.[xl] The estimate for each stretch of road involved in the project to reach terminal serviceability varies from 6 to 15 years. The calculations used to render these values can be found in Appendix G. Under the build scenario the road would be designed to withstand around forty-four times more ESALs over its lifetime.[xli]

In our no-build scenario, we assume routine maintenance including routine crack-sealing and pothole filling, until the point at which the road will have 980,000 ESALs and needs to be resurfaced. Transportation engineers told us that a road's quality typically lasts three years after it has been resurfaced. During this time period, roads typically need very little maintenance, beyond winter snow-plowing and salting. Under the no-build, we assume that the three years (or roughly 4,000 cumulative vehicles) after a road has been paved, routine maintenance costs are $0. At the end of this time period (3 years or 4,000 cumulative vehicles), we assume the county resumes standard crack-sealing and pothole filling (which we estimate costs between $300 and $324 per mile).[xlii]

Under the project scenario, a more resilient road will need less routine maintenance. Transportation engineers said that typically no maintenance is needed for five years after a resurfacing project has been finished. In our model, we assume that summer maintenance costs in the first five years after the project has been completed will be $0. Additionally, an all-season highway will last longer until it needs to be resurfaced. We assume that Highway A would not need to be resurfaced until a cumulative total of 30,000 vehicles have driven on it.[xliii]

Winter Maintenance

The cost of winter maintenance—snow-plowing and salting the roads—was estimated from historic winter maintenance costs in Bayfield County. Bayfield County provided the total cost of winter maintenance for the past five years. These values were divided by the total mileage of county highways (172) to find the cost per mile for each year. After scaling each year's cost per mile for inflation, we assumed future costs would fall in a normal distribution between the low-cost year (2015) and the high-cost year (2013). Since 2015 was a historically low snowfall year and 2013 was a historically high snowfall year, we believe the costs from these years form reasonable bounds to our winter maintenance projections.[xliv]

Timber Bids

Research on seasonal logging restrictions has indicated that the presence of restrictions can depress timber bid prices by as much as much as 20%. Logging respondents are willing to pay more for a timber tract if they have access to it during more of the year, other things being equal. Seasonal load restrictions can prevent logging respondents from harvesting and selling wood for more than two months, reducing the amount that they are willing to bid on a tract. While research has not been done on the magnitude to which tract bids are reduced when seasonal load restrictions are in place, industry surveys indicate that the value may increase by as much as 15%.[xlv]

To estimate the increase in bid values attributable to making Highway A an all-season road, we analyzed the county's forest bid data to derive an average bid per acre. While many factors go into the value that a logger places on the tract, including the mix of tree species, terrain type, and market conditions, access and proximity to processing locations are important variables.[xlvi] Based on discussions with forestry researchers and a professional forester from Bayfield County, we assume that the average per acre bid price could increase by anywhere between 10% and twenty 20%. This analysis assumes that the distribution would skew toward the upper end of that range (between an increase of 15% and 20%), given the value of the resources along Highway A. We believe this may be a conservative estimate of the true magnitude of benefits since most of the county forest tracts along highway A are on sandy soil, which is the most valuable to logging respondents.

Monte Carlo Sensitivity Analysis

Uncertainty exists in every cost-benefit analysis. To account for the uncertainty in our cost and benefit projections, we conducted a Monte Carlo sensitivity analysis. A Monte Carlo sensitivity analysis randomly generates variables based on the conditions we establish. It essentially simulates the highway improvement project's costs and benefits. It recreates the scenario 1000 times using random variables and provides a range of likely values for the costs and benefits in each year of a project's life.

The first step in our analysis was to create random variables for both the no-build scenario and for the scenario where Bayfield County uses a BUILD grant to improve Highway A and Highway N. Below is a table of the variables defined, their mean, their standard deviation (if applicable), and what type of distribution was used in the Monte Carlo simulation.

Table 1: No-Build Scenario Variables

Variable	**Mean**	**Standard Deviation**	**Distribution [range]**
Winter maintenance costs	$5,159/mile	$761/mile	Uniform [$4000, $6070]
Number of trucks	44 trucks/day	9.6 trucks	Uniform [-5%, +5%]
Routine (summer) maintenance	$5,000/mile	n/a	Uniform [-10%,+ 10%]

Table 2: Build Scenario Variables

Variable	**Mean**	**Standard Deviation**	**Distribution [range]**
Winter maintenance costs	$4,127/mile/year	$609/mile	Uniform [$3200, $4800]
Road Quality	n/a	n/a	Uniform [mean, +10%]

Number of trucks	44 trucks/day	9.6 trucks	Uniform [-5%, +5%]
Routine (summer) maintenance	$5,000/year	n/a	Uniform [-5%, +5%]
Total construction costs	$720,756.17/mile	n/a	Uniform [-5%, +5%]
Travel time savings	$3,765/mile	n/a	Uniform [-10%, +10%]
Average logging bid increase	$1,967,994*15%	+5%	Normal [min 10%, max 20%]

Our Monte Carlo analysis took the following steps:

1. Calculate cost by calculating the sum of all cost variables and discounting them for each year at a rate of 7%.
    1. Calculate PV of cost for no-build, discounted

$$\sum_{t=1}^{26} \frac{(summer\ status\ quo\ maintenance_t + winter\ status\ quo\ maintenance_t)}{(1\ +\ 0.07)^t}$$

    2. Calculate PV of cost for BUILD scenario, discounted

$$\sum_{t=1}^{26} \frac{(summer\ BUILD\ maintenance_t + winter\ BUILD\ maintenance_t + construction_t)}{(1\ +\ 0.07)^t}$$

    3. Take the difference between the cost of no-build scenario and the cost of no-build

$$\sum_{t=1}^{26} \frac{(summer\ status\ quo\ maintenance_t + winter\ status\ quo\ maintenance_t)}{(1 + 0.07)^t} -$$

$$\sum_{t=1}^{26} \frac{(summer\ BUILD\ maintenance_t + winter\ BUILD\ maintenance_t + construction_t)}{(1\ +\ 0.07)^t}$$

2. Calculate benefits by calculating the sum of all benefits variables and discounting them for each year at a rate of 7%.
    1. Calculate PV of benefits for no-build, discounted

$$\sum_{t=1}^{26} \frac{(\ timber\ status\ quo\ revenue_t)}{(1\ +\ 0.07)^t}$$

2. Calculate PV of benefits for BUILD scenario, discounted

$$\sum_{t=1}^{26} \frac{(\ timber\ BUILD\ revenue_t + time\ savings_t)}{(1\ +\ 0.07)^t}$$

3. Take the difference between the benefits of BUILD scenario and the benefits of no-build

$$\sum_{t=1}^{26} \frac{(\ timber\ status\ quo\ revenue_t)}{(1\ +\ 0.07)^t} - \sum_{t=1}^{26} \frac{(\ timber\ BUILD\ revenue_t + time\ savings_t)}{(1\ +\ 0.07)^t}$$

3. Calculate the residual value of the project using a linear decay function.
4. Present the net costs and net benefits.

Results

Costs

Maintenance

The present value of the cost of maintenance for the project route under the no-build scenario is estimated to be $2.83 million (plus or minus $83,000, with 95% certainty). This value reflects twenty years of routine maintenance, including annual plowing, regular crack-sealing, and occasionally resurfacing.

The present value of the cost of maintenance for the project route under the build scenario, in which Highway A is reconstructed is estimated to be $1.84 million (plus or minus $121,000, with 95% certainty). This value reflects a stronger road that needs routine maintenance less often, a road with reduced winter maintenance costs, as well as more asphalt that can be recycled (“scrapped”) when the road needs to be resurfaced.

Construction

The present value of the costs of the entire build scenario, including the cost of construction, is estimated to be $19.3 million (plus or minus $790,000, with 95% certainty). This includes the $700,000 construction per lane mile for 16.47 miles of Highway A and $213,452 resurfacing per lane mile for 5.82 miles of Highway N, plus all overhead. Compared to the no-build scenario, the construction scenario costs $12.8 million more.

Table 3: Costs (in millions)

Cost Category	No-Build Scenario			Build Scenario			Cost Savings
	Mean	*Min*	*Max*	*Mean*	*Min*	*Max*	
Motor Vehicle Accidents	$3.7	$3.0	$4.7	$1.4	$0.98	$1.9	$2.3
Maintenance	$2.83	$2.75	$2.91	$1.84	$1.67	$1.96	$0.99
Project Cost				$16.1	$15.9	$16.3	-$16.1
Total Costs	**$6.53**	**$5.75**	**$7.61**	**$19.3**	**$18.6**	**$20.2**	**-$12.8**

Benefits

Timber

The present value of the increase in timber revenues is estimated to be $3.3 million (plus or minus $0.51 million, with 95% certainty). These revenues are roughly equally split between Bayfield County and the federal government.

Safety Benefits

The present value of the decrease in car crashes is estimated to be $2.4 million, representing a decline from a cost to society of $3.8 million under the no-build scenario to $1.4 million with a reconstructed road. This reflects a decrease in crashes from an average of five per year, to an average of one. The motor vehicle accidents are accounted for in the costs table above.

Job Benefits

The present value of the increase in jobs is estimated to be $2.8 million (plus or minus $1.1 million, with 95% certainty). This reflects an increase of 13 jobs, on average in the region.

Travel Time Benefits

The present value of travel time savings is an average of $297,223 (plus or minus $8,835, with 95% certainty). This reflects a time savings of approximately 3 seconds for each driver per trip.

Table 4: Benefits (in millions)

Benefit Category	**No-Build Scenario**			**Build Scenario**			**Benefits Improvements**
	Mean	*Min*	*Max*	*Mean*	*Min*	*Max*	
County and Federal Revenue from Timber Sales	$22.3	$21.8	$22.7	$25.6	$25.1	$26.1	$3.3
Travel Time Savings				$0.30	$0.27	$0.32	$0.30
Added Employment				$2.82	$.68	$5.84	$2.82
Total Benefits (Monte Carlo-adjusted)	**$22.3**	**$21.8**	**$22.7**	**$28.7**	**$26**	**$32.3**	**$6.4**

Residual Value

The residual value of a proposed project is the estimated value of the project's assets at the end of the period of analysis, representing their expected value in continuing use. In the case of the proposed project in Bayfield County, the residual value represents the continued use of the road. Under the no-build scenario the benefits are fewer compared to the build scenario due to the fact that none of the improvements have been undertaken. Under the build scenario, even after the project has been built and been through one lifecycle, the county will have a much larger, all-season road, with a higher crown, smoother grade, and a larger shoulder. The proposed road improvement would continue to be an asset to the county for decades to come.

Present Value of Net Benefits

The table reflects the present values of the monetized costs and benefits for both scenarios, discounted at a 7% rate over twenty years.

Table 5: Present Value of Net Benefits (in millions)	
Present Value Costs for BUILD Scenario	($19.3)
Present Value Benefits for BUILD Scenario	$28.7
Residual Value of Road for BUILD Scenario	$2.67
Net benefit, build scenario	**$12.1 million**
Present Value Costs for No-Build Scenario	($6.5)
Present Value Benefits for No-Build Scenario	$22.3
Residual Value of Road for No-Build Scenario[4]	$0.45
Net benefit, no-build scenario	**$16.3 million**

Benefit-Cost Summary

The additional forest revenues, travel time savings and added employment result in the following Benefit Cost Summary at a 3% and 7% Discount Rates:

	3% Discount Rate	**7% Discount Rate**
Benefits	$39.1 million	$31.4 million
Costs	$20.4 million	$19.3 million
Benefit/Cost Ratio	1.92	1.63

Conclusion

Updating Highway A to an all-season road will make the highway more resilient and will reduce maintenance costs. It will also positively impact economic development through better

[4] Residual value of the road past the year 2042

forest access, improved marketability of forest product and job creation in both the tourism and forestry sectors of the local economy.

The net Benefit Cost Analysis in this evaluation is based on increased community benefits versus the cost of the project. The present value of net benefits for the no-build scenario is approximately $4.2 million more than the quantifiable present value of net benefits for the build scenario. When accounting for uncertainty, the present value of net benefits for constructing the highway is approximately $12.1 million.[5]

We estimate that the highway will cost about $15.1 million more to construct and maintain than the no-build scenario. This is largely a product of the upfront cost of reconstructing the highway. If the highway is not improved, our calculations suggest that the present value of the money that the county will spend over the next 25 years on maintaining the current highway is $2.83 million, or $290,000 more than they would spend on maintenance in the build scenario.

The cost of highway construction will be partially recouped through higher timber bids. We estimate that increased values on timber bids along Highway A will bring in an additional $3.3 million from both county and federal forests, over the next twenty years (discounted at a rate of 7%). Under the no-build scenario, we can expect that the present value of the timber bids over the next twenty years will be $22.3 million. After the highway improvement, that value increases to $25.6 million.

Road construction comes with many benefits, some difficult to quantify. Reductions in travel time and vehicle emissions are two of these. Such changes are difficult to monetize: there is no established criteria for monetizing carbon dioxide, sulphur dioxide, or other pollutants that cars emit.

Other variables, including the economic impact of job increases, the value of reducing harmful chemical emissions, and vehicle collisions are difficult to quantify but are expected to have a positive impact on the benefits of this project. We believe that the estimate presented in this report is a conservative under-estimate of the true value of this project's benefits.

5 Generated by Monte Carlo analysis.

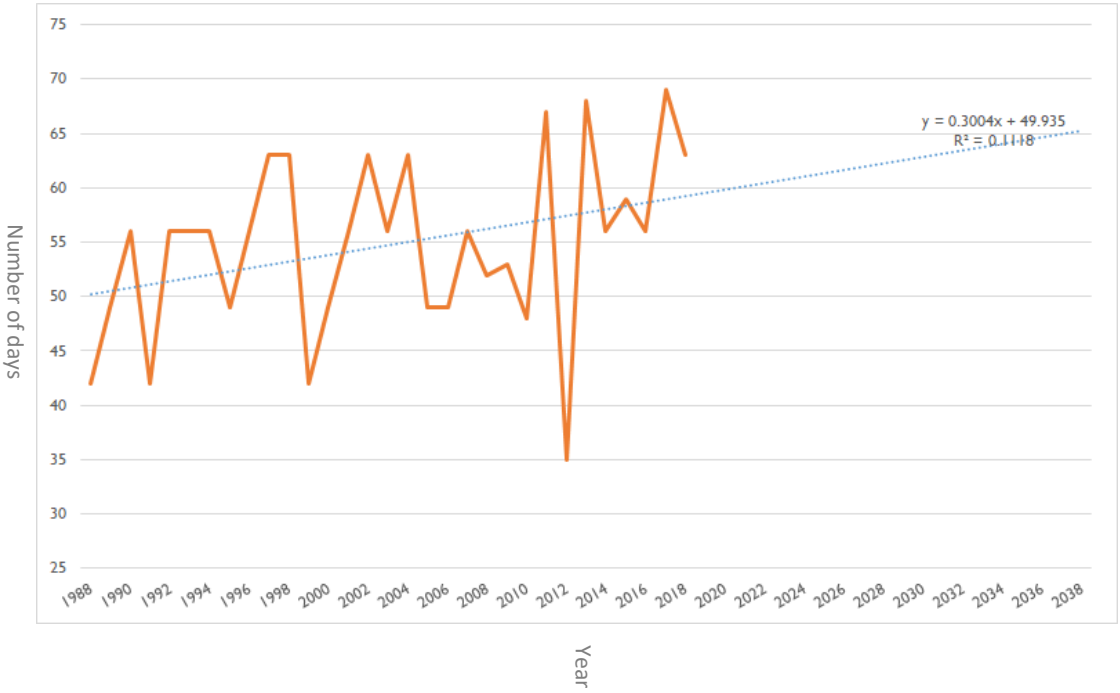
Appendices

Appendix A: Length of Thaw Restrictions

Over the past 30 years, spring load restrictions have been in force in Bayfield, Ashland, and Douglas counties for an average of 54 days. As Wisconsin's springs have gotten warmer and wetter, however, the length of the spring thaw season has increased.[xlvii] In the five years between 2014 and 2018 (inclusive), spring load restrictions have been in force for an average of 58 days.[xlviii]

The figure below shows the length of spring load restrictions in each year since 1988. There is wide variation in the length of spring load restrictions, consistent with year-to-year fluctuations in climate. The shortest load restriction occurred in 2012, lasting only 35 days; the longest occurred in 2017, lasting 69 days. However, the long-term trend has been toward growth: roughly every three years, the length of the spring weight restriction period is expected to increase by one day. Over the course of the 20-year time span used by this report, we can expect that spring load restrictions will last a week longer than they currently do.

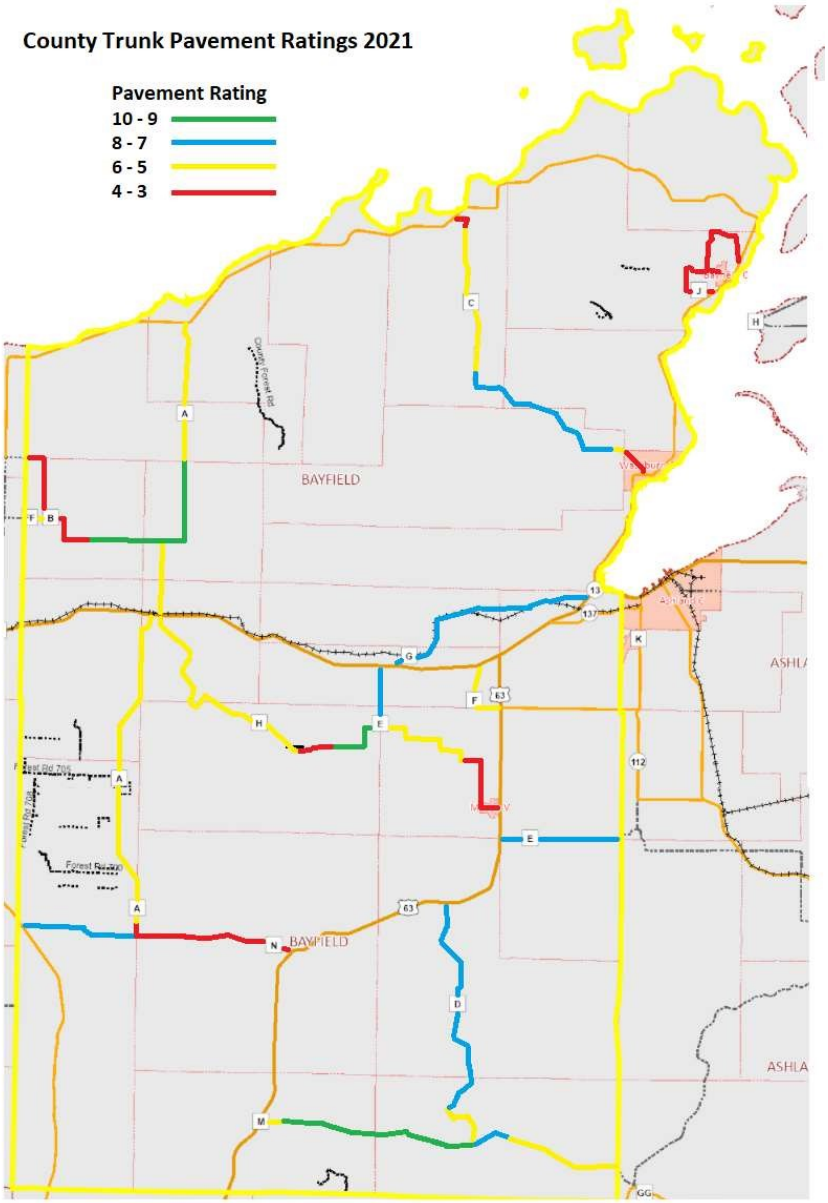
Figure A.1: Historic Length of Spring Load Restrictions



Appendix B: Map of Road Conditions

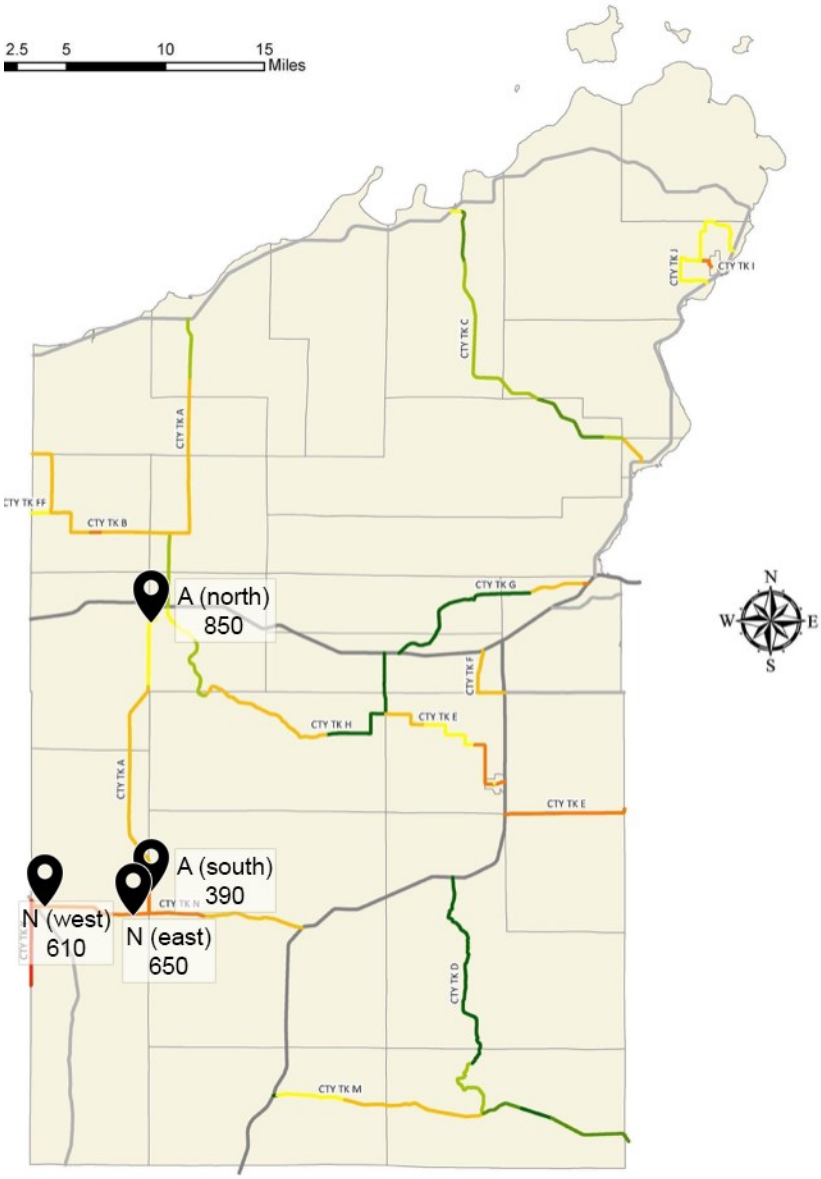
Map B shows the PASER rating of all of Bayfield county's county highways. Highway A is located in the center right section of the county, running from its intersection with U.S. route 2 in Iron River to its terminus at Highway N in Barnes. The project highway then follows Highway N west to its intersection with Wisconsin State Highway 27. Project area-specific ratings can be seen on B.2 PASER ratings are expected to decline 1 point every two years.

Map B: PASER Rating of Bayfield County Highways



Appendix C: Traffic Counts

Map C.1: Traffic Count Locations

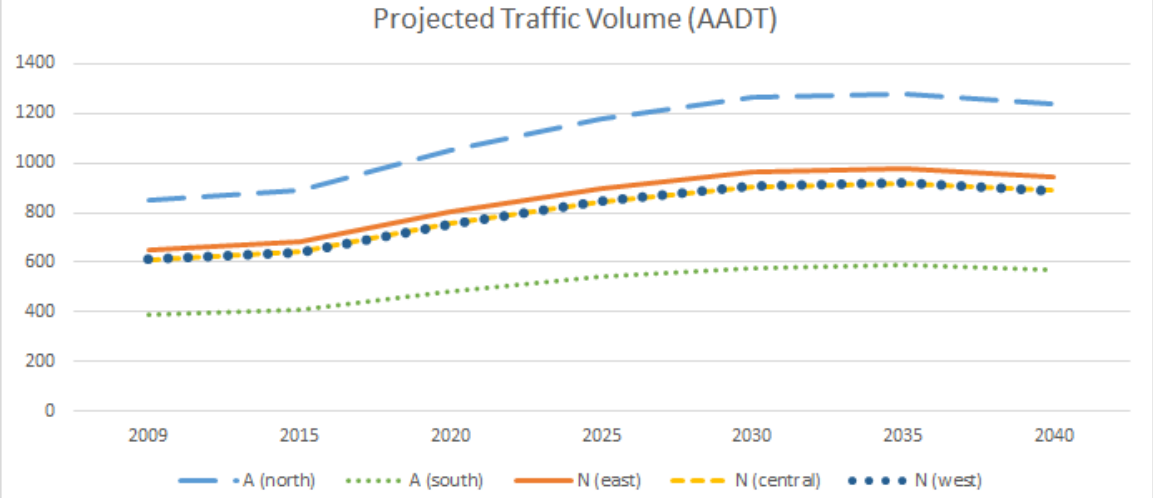


Appendix D: Traffic Growth Projections

Table D.1: Projected Traffic Counts (average annual daily traffic)

Location	Year						
	2009	*2015*	*2020*	*2025*	*2030*	*2035*	*2040*
A (north)	850	892	1078	1176	1262	1280	1239
A (south)	390	409	495	540	579	587	568
N (east)	650	682	824	900	965	979	947
N (central)	610	640	773	844	906	919	889
N (west)	610	640	773	844	906	919	889

Figure D.1: Projected Traffic Counts



These traffic counts are forecasted using a method that relates various demographic and economic variables in order to relate rural population counts to traffic levels. Future average annual daily traffic (AADT) is filtered through thirteen variables including vehicle registration data, county population, gas tax information, and employment numbers, to predict future traffic.[xlix]

Appendix E: Travel Time Equations

Time Value^{l} = (Percentage of commuters using this route)*(vehicle occupants)*(average Bayfield County wage) + (Percentage of truckers using this route)*(Vehicle occupants)*(trucker wage) + (Percentage of tourists using this route)*(vehicle occupants)*(average hourly earnings for Minneapolis, Madison, and Duluth) = $XX/h

Annual Travel Time Benefit = (time saved by new road)* (Time Value)*(number of vehicles per day)*(365 days/year)= $XX/h

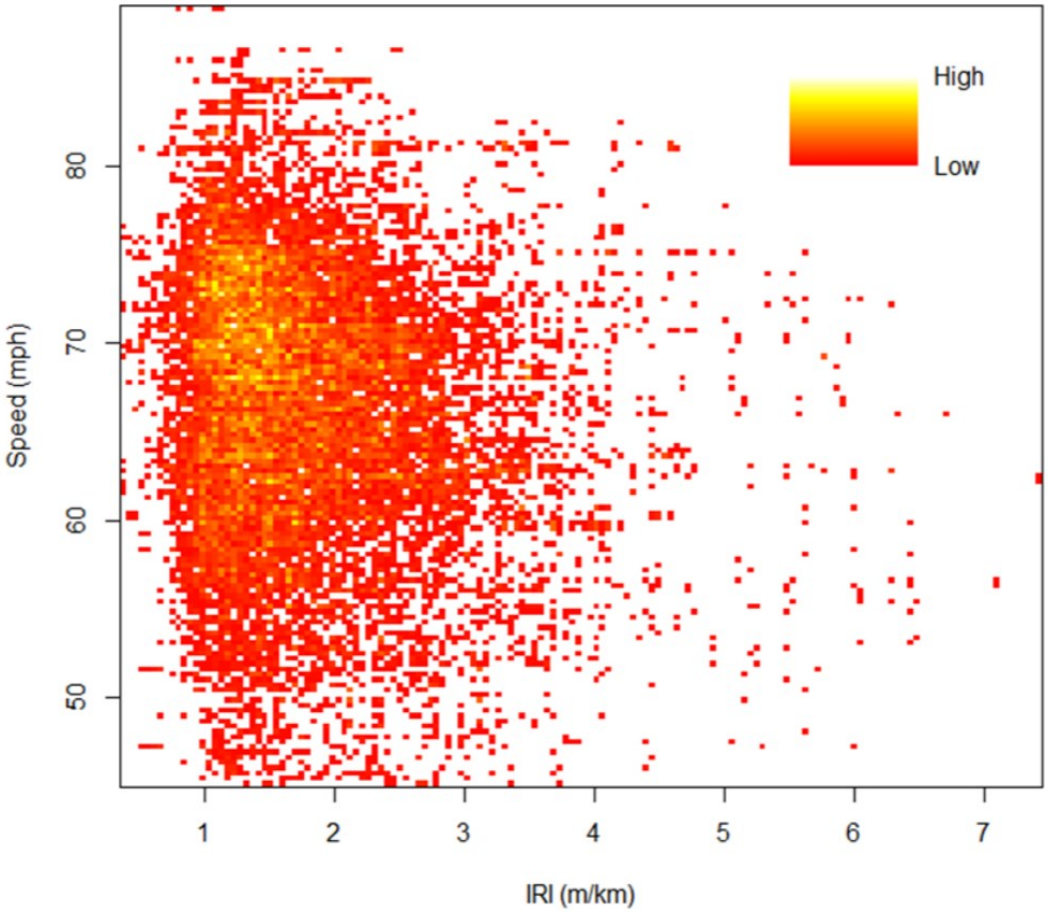


Figure 2.9: Density plot of IRI and speed observations. (Note: 1 m/km = 63 inches/mile.)

Appendix F: Road Maintenance Assumptions and Calculations

Assumptions:

1. Classification as a "Flexible" pavement and as a "Rural Other Principal Arterial" [li]
2. Equivalent single axle load: Highways A and N have an ESAL Life of 980,000 [lii]
3. Logging trucks using these stretches of road have a "truck factor" of 2.41 [liii]
4. Directional Distribution factor of 50; the percentage of drivers on either side of the road[6]
5. Percentage of traffic consisting of trucks: 20%
    1. Estimate shared by emissions and travel time improvements
6. Growth Rates[liv]
    1. 2015-2020: 3.63%
    2. 2020-2025: 2.32%
    3. 2025-2030: 1.47%
    4. 2030-2035: 0.28%
    5. 2035-2040: -0.64%
7. Initial pavement serviceability rating (PSR) of 4.2, terminal PSR of 2.5 [lv]
    1. Therefore, a maximum tolerable decline of 1.7 PSR
8. Life-Term Pavement Performance: 14.9 Years [lvi]
9. Service life of 20 years
10. Assuming a "Wet Freeze" climate[7]

Climatic Zones of the U.S. [lvii]

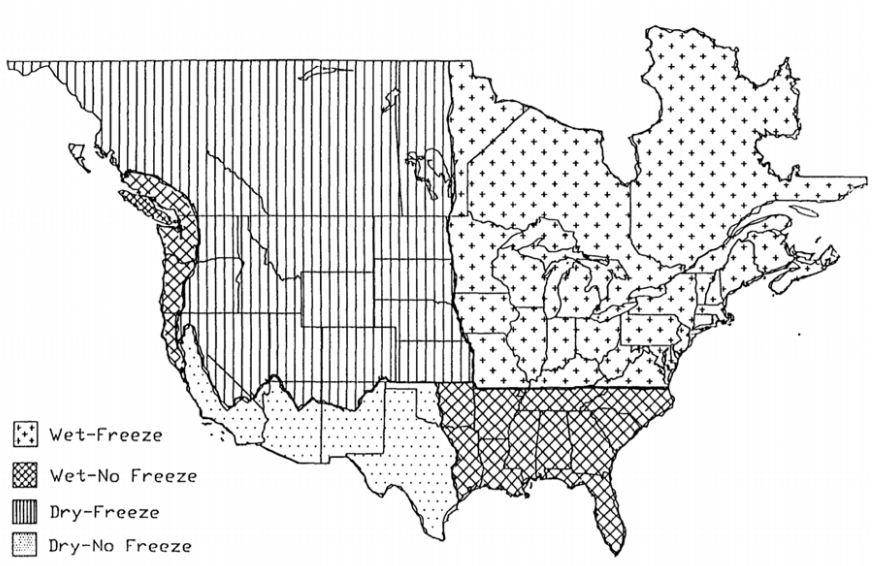


Figure 3. Climatic zone.

[6] Taken from Bayfield traffic count projections

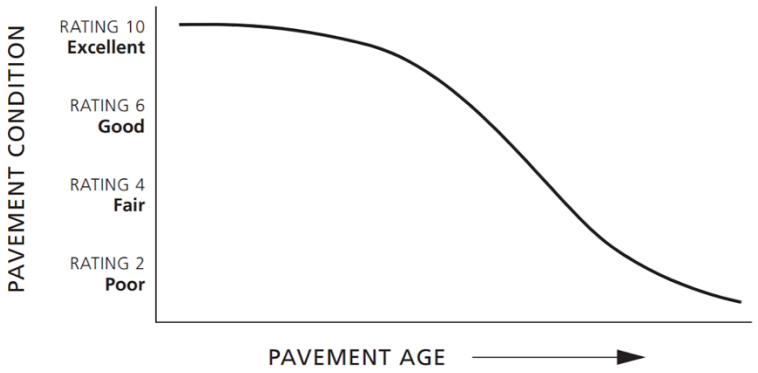
[7] See "Figure 3. Climatic Zone."

Appendix G: Comparison of Rating Systems

In the course of our analysis, we have had to utilize a handful of different pavement rating systems. These include PASER (Pavement Surface Evaluation and Rating), PSR (Present Serviceability Rating), IRI (International Roughness Index), and PCI (Pavement Condition Index). These four rating systems differ in a myriad of ways. This section of the report serves to explain the ways that the rating systems can be compared to one another.

PASER

The PASER rating system was created in Wisconsin at the University of Wisconsin-Madison Transportation Information Center.[lviii] According to the *Asphalt Road PASER Manual*, "PASER uses visual inspection to evaluate pavement surface conditions." Damage to the road is identified, categorized, and linked to a cause. The major factors that play into the assignment of a PASER rating are surface defects (described as "raveling, flushing, and polishing"), surface deformation (rutting and distortions), cracks, patches, and potholes.[lix] PASER does not directly address the quality of a road's foundation, but extrapolates it based on surface distress. PASER rates pavements on a scale of 10 to 1; one visual iteration this scale can be seen below.



In addition to indicating the surface condition of a road, a given rating also includes a recommendation for needed maintenance or repair. This feature of the rating system facilitates its use and enhances its value as a tool in ongoing road maintenance.

RATINGS ARE RELATED TO NEEDED MAINTENANCE OR REPAIR

Rating 9 & 10	No maintenance required
Rating 8	Little or no maintenance
Rating 7	Routine maintenance, cracksealing and minor patching
Rating 5 & 6	Preservative treatments (sealcoating)
Rating 3 & 4	Structural improvement and leveling (overlay or recycling)
Rating 1 & 2	Reconstruction

A detailed version of the PASER rating system:

Rating system

Surface rating	*Visible distress**	*General condition/ treatment measures*
10 Excellent	None.	New construction.
9 Excellent	None.	Recent overlay. Like new.
8 Very Good	No longitudinal cracks except reflection of paving joints. Occasional transverse cracks, widely spaced (40' or greater). All cracks sealed or tight (open less than ¼").	Recent sealcoat or new cold mix. Little or no maintenance required.
7 Good	Very slight or no raveling, surface shows some traffic wear. Longitudinal cracks (open ¼") due to reflection or paving joints. Transverse cracks (open ¼") spaced 10' or more apart, little or slight crack raveling. No patching or very few patches in excellent condition.	First signs of aging. Maintain with routine crack filling.
6 Good	Slight raveling (loss of fines) and traffic wear. Longitudinal cracks (open ¼"–½"), some spaced less than 10'. First sign of block cracking. Sight to moderate flushing or polishing. Occasional patching in good condition.	Shows signs of aging. Sound structural condition. Could extend life with sealcoat.
5 Fair	Moderate to severe raveling (loss of fine and coarse aggregate). Longitudinal and transverse cracks (open ½") show first signs of slight raveling and secondary cracks. First signs of longitudinal cracks near pavement edge. Block cracking up to 50% of surface. Extensive to severe flushing or polishing. Some patching or edge wedging in good condition.	Surface aging. Sound structural condition. Needs sealcoat or thin non-structural overlay (less than 2")
4 Fair	Severe surface raveling. Multiple longitudinal and transverse cracking with slight raveling. Longitudinal cracking in wheel path. Block cracking (over 50% of surface). Patching in fair condition. Slight rutting or distortions (½" deep or less).	Significant aging and first signs of need for strengthening. Would benefit from a structural overlay (2" or more).
3 Poor	Closely spaced longitudinal and transverse cracks often showing raveling and crack erosion. Severe block cracking. Some alligator cracking (less than 25% of surface). Patches in fair to poor condition. Moderate rutting or distortion (1" or 2" deep). Occasional potholes.	Needs patching and repair prior to major overlay. Milling and removal of deterioration extends the life of overlay.
2 Very Poor	Alligator cracking (over 25% of surface). Severe distortions (over 2" deep) Extensive patching in poor condition. Potholes.	Severe deterioration. Needs reconstruction with extensive base repair. Pulverization of old pavement is effective.
1 Failed	Severe distress with extensive loss of surface integrity.	Failed. Needs total reconstruction.

** Individual pavements will not have all of the types of distress listed for any particular rating. They may have only one or two types.*

PSR

Created by the American Association of State Highway and Transportation Officials, PSR, or Present Serviceability Rating, is based on a visual evaluation of the road segment, making it similar to PASER. PSR is commonly used when IRI data is not available. Also similar to PASER, PSR uses a number scale, this one from 5.0 to 0.1, with 5 being the best rating and 0.1 the lowest. One major difference between the two scales comes from the lack of recommended maintenance in the PSR which is available through PASER. However, the two scales are similar enough in their descriptions of the various number ratings, that one could simply double the PSR rating for a road segment and relate it to its PASER equivalent. The PSR scale:

1. 4.0 – 5.0: Only new (or nearly new) superior pavements are likely to be smooth enough and distress free (sufficiently free of cracks and patches) to qualify for this category. Most pavements constructed or resurfaced during the data year would normally be rated in this category.

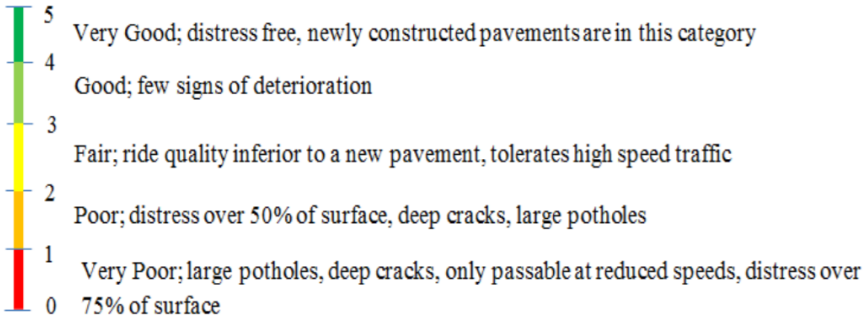
2. 3.0 – 4.0: Pavements in this category, although not quite as smooth as those described above, give a first-class ride and exhibit few, if any, visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration, such as minor cracks and spalling.

3. 2.0 – 3.0: The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking, and extensive patching. Rigid pavements in this group may have a few joint failures, faulting and/or cracking, and some pumping.

4. 1.0 – 2.0: Pavements in this category have deteriorated to such an extent that they affect the speed of free-flow traffic. Flexible pavement may have large potholes and deep cracks. Distress includes raveling, cracking, rutting and occurs over 50 percent of

the surface. Rigid pavement distress includes joint spalling, patching, cracking, scaling, and may include pumping and faulting.

5. 0.1 – 1.0: Pavements in this category are in an extremely deteriorated condition. The facility is passable only at reduced speeds, and with considerable ride discomfort. Large potholes and deep cracks exist. Distress occurs over 75 percent or more of the surface.



For example, the PASER description of 4-rating road is “severe surface raveling...transverse cracking...block cracking (over 50% of surface).” The same description for a 2-rating on the PSR scale is “distress over 50% of surface, deep cracks, large potholes.” This trend holds true throughout both scales. We therefore assume that PSR and PASER are comparable metrics and that the conversion is PASER=2*PSR.

IRI

Developed by the UN and The World Bank, the International Roughness Index (IRI) is much different than PSR and PASER. Rather than a visual inspection of the road, the IRI is a measurement of how rough the road segment is. This measurement can be taken in a variety of ways, but the results are essentially a measurement of how much a vehicle’s suspension moves while traveling down the specified stretch of road. The scale is reported in millimeters or inches, and the further from zero that the road strays, the higher the roughness.

Another major difference between IRI and both PASER and PSR, is that IRI is tabulated as the survey vehicles drives over the road segment, while under PASER and PSR the roads need to be assigned values manually by the observers. This does not, however, mean that the two

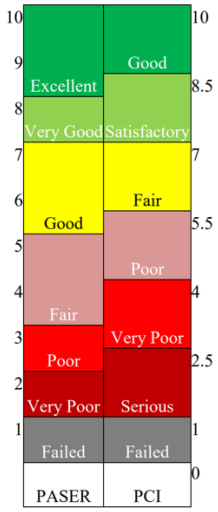
cannot be synchronized. One study done at Purdue University shows a "very strong correlation between IRI and PASER when individual measurements are averaged together for an entire county."[lx] This correlation was not as strong on the individual road segment level.

For our analysis, we relate IRI to reductions in travel time. Our analysis only necessitates a loose relationship between IRI and PASER; we assert that the PASER scores of the road segments in question, which have scores of 4 and 5, imply that the IRI is less-than-perfect and will be improved if the reconstruction project is undertaken. Therefore, we do not need to delineate a direct relationship between IRI and PASER or PSR.

PCI

The pavement condition index (PCI) rating system was designed by the US Army Corps of Engineers. It uses a visual survey of the pavement to generate statistics that are processed and standardized. The rating system uses a scale of 100 to 0, with 100 being the best possible condition.

As is the case with IRI and PASER, PCI and PASER are not strongly correlated at the road segment level but yield similar results when evaluating entire road systems.[lxi] Short road segments may not have strong correlation between PASER and PCI scores (their scales are similar, as can be seen in Figure 2). Therefore, we must be conservative when extrapolating PASER to PCI. A PASER score of 5 to 4 would roughly translate to between a 5.5 and 2.5 on the PCI scale, or "poor" and "very poor."



Appendix H: Bayfield County Highway Survey Questions and Results

Q1 - Which best describes you? (select all that apply)

Answer	%	Count
Logger	18.42%	28
Farmer	5.26%	8
Truck Driver	15.13%	23
Other Industrial User	6.58%	10
Highway A or N Resident	6.58%	10
Forest Land Owner, Private	7.89%	12
Forest Land Owner, Large Industrial	1.32%	2
Bayfield County full time resident	30.92%	47
Bayfield County seasonal resident	3.95%	6
Other	3.95%	6°
Total	**100%**	**152***

**Because respondents could choose more than one answer, the total is greater than the actual number of responses*
° Of the 6 "Other" responses, 2 chose just Other with no additional categories chosen. Of the 6 "Other" responses; no one had written in a description

Q2 - Would these all season county highways allow you to bid higher on timber sales?

Answer	%	Count
Yes	80.00%	16
No	20.00%	4
Total	**100%**	**20***

**Only those who chose Logger in Question 1 could answer this question.*

Q3 - How do you adjust your logging practices while load restrictions are in place (select all that apply)?

Answer	%	Count
Staging wood at accessible landings	13.04%	3
Accessing forests through alternate routes	0.00%	0
Planning seasonal harvest schedule around load restrictions	78.26%	18
Not applicable: do not operate in spring	0.00%	0
Other, please specify:	8.70%	2°
Total	**100%**	**23***

**Only those who chose Logger in Question 1 could answer this question.*

Q3 - Other, please specify°:

bid lower on sales not accessible
All of the above.

Q5 - What Impact would all season county highways/no spring postings have on you/your operation?

Answer	%	Count
Very positive impact	67.65%	23
Positive Impact	23.53%	8
Neutral	8.82%	3
Negative Impact	0.00%	0
Very Negative	0.00%	0
Total	**100%**	**34***

*Those who answered Logger, Farmer, Truck Driver or Other Industrial User in Question 1 could answer this question.

Q6 - Would all season county highways allow you to expand your business?

Answer	%	Count
Yes	83.33%	20
No	16.67%	4
Total	**100%**	**24***

*Those who answered Logger, Farmer, Truck Driver or Other Industrial User in Question 1 could answer this question.

Q7 - Would all season county highways increase the number of people you employ?

Answer	%	Count
Yes, I would be able to hire more people, approximately (please use a number such as 1, 2, 3, not in words such as "a few".	45.45%	10
No	54.55%	12
Total	**100%**	**22***

*Those who answered Logger, Farmer, Truck Driver or Other Industrial User in Question 1 could answer this question.

Q7– Please use a number such as 1, 2, 3, not words such as a "few"

Raw Data	# of Employees	# of Respondents
1	1	3
6	2	5
2	3	1
2	6	1

Q4 - How frequently do you use Highway A? (select one)

Answer	%	Count
Never	5.75%	5
Very rarely (1 - 6 times a year)	12.64%	11
Rarely (7 – 11 times a year)	10.34%	9
Occasionally (1 – 2 times a month)	14.94%	13
Frequently (3 - 5 times a month)	17.24%	15
Very frequently (more than five times a month)	37.93%	33
Not Applicable: not a heavy user	1.15%	1
Total	**100%**	**87***

*All respondents could answer this question

Q10 - Do you have any other comments about upgrades to County highways?

County A and all of County N need to be fixed. County Y is altogether the worst road in the county!
Work is needed on County A NORTH of Iron River, too!
Just would appreciate the upgrades, I drive it pretty much daily
Daily. Live on highway A
If the road base is built correctly then there would be minimal impact on the road even during springtime.

Daily as I live on A.

These truly need repaired. I cannot do close to the speed limit when pulling a trailer.

Has needed some attention for a long time. It allows easy access to and from Iron River and increases availability of surrounding communities.

Due to increasing bike traffic, please make wider shoulders.

). No

1. Every county highway should be upgraded to haul 98000 lbs. Year-round.

2. The reconstruction of A would be beneficial not only for year-round use but to make the rode more functionable. There are many dips and bumps in the road.

3. Our roads should be built to a standard that allows business to continue year-round, sidelining industries for 2-3 months a year because of the inability to build a proper road is foolish.

4. All season access to the valuable natural resources in this area are crucial to the local economy, land managers, logging respondents, truckers and forest products companies that help convert our timberland in finished forest products.

5. As a retired U.S.Forest Service Timber technician, I know how important it can be to have good access routes all year long, for timber and timber machinery hauling. That being said, I've seen the damage caused by trucks that haul when load limits are on in the spring. Some of these roads will never get funding to have that kind of use. I do support upgrading of A and D if possible. In addition, I support active law enforcement of load limits. I know of many haulers who think that they can haul all year, and make up reasons to do so; times are tough and waiting a month to haul is hard. Having a pre-haul spot isn't always possible. I've known company owners who force employees to haul. I've known at least one County board member that owns a timber company; who insisted on hauling during breakup. One owner stated that all blacktop roads should be built to carry year-round truck traffic; good point, but expensive. I fought hard for the timber industry during my career and always set up the best sales that I could for logging profit and efficiency. We need this industry!

5. County C would be the most important upgrade because the alternate route is to have to use Highway 13 through Bayfield.

7. any upgrades, so that logging respondents could haul wood all year round, would definitely help the struggling logging respondents

3. Upgrading county highways would have a very positive impact on the local timber industry.

). Are there any kinds of streams in the area? While these repairs are happening, it may be advantageous to "upsize" or change the angle/pitch of any culverts in the area to reduce flooding potential and allow better fish passage. Angling and tourism are important industries in Bayfield County too. Same goes for replacing power lines and telecoms cables for businesses and residents, if applicable.

). It would be such a help to all industry. It creates such a hardship and expense dealing with posted roads. For two months a year we are basically shut down to make a living.

Appendix I: Crashes on the Project Route

Year	Crashes	Injuries
2017	4	3
2018	7	3
2019	6	0
2020	5	1
2021	4	1

Appendix J: The KABCO Scale

KABCO is a standardized system of rating the severity of automobile crashes. The scale is based on the injuries sustained by victims in a crash. Table I.1 explains the severity rating and lists the inflation-adjusted costs to society of accidents.

Table I.1: KABCO Crash Severity Scale and Costs

Rating	Explanation[lxii]	Cost to Society[lxiii] (2018)
K	Any injury received in a traffic accident which results in death within 30 days of the accident.	$1,854,044
A	Any injury other than a fatal injury which prevents the injured person from walking, driving, or from performing other activities which he/she performed before the accident	$154,913
B	Any injury, other than fatal or incapacitating, which is evident at the scene. Evidence of injury may include known symptoms an injury which are not directly observable	$56,895
C	Any injury which is not observable or evident at the scene but is claimed by the individual or suspected by the law enforcement officer	$39,838
O	No injuries	$7,126

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